A Simple Empirical Formula for Calculating Approximate Surface Area in Children

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Human body surface area was extensively measured and calculated in the 19th century (Meeh, 1879), and its correlation with caloric needs and renal clearances was demonstrated several decades ago (Gephart and Du Bois, 1915; West, Smith, and Chasis, 1948). Because it seems to correlate well, accidentally or not, with the known variation of dosage with size, it has also been used as a basis for fluid therapy and drug dosage (Butler and Richie, 1960).

The usefulness of surface area in clinical practice is limited by its difficulty of calculation. The standard formulae now in use (Du Bois and Du Bois, 1916; Boyd, 1935) are far too complex to use for bedside calculation. Nomograms based on these formulae have been evolved, but they also have disadvantages at the bedside. A simple formula, capable of being calculated on the back of an envelope, would be useful.

Surface area is usually calculated from weight and height, or from height alone. Comparisons of measured surface area with either or both of these parameters have shown considerable scatter, so that even the most perfect formula based on weight and height will deviate from the measured value by over 6% in at least a third of the cases (Boyd, 1935). A formula for surface area may therefore be considered accurate if its root-mean-square deviation from measured area is less than 10%.

The problem of deriving an equation for surface area has no single general solution because the human body is an irregularly shaped solid, with irregular and inconstant rates of growth of its different dimensions. Any formula used must be empirical. In such a case it is possible either to take a formula for a regular solid and then complicate it by changing exponents and coefficients, as did Boyd (1935) and Du Bois and Du Bois (1916), or to use empirical formulae which bear no relation to the geometric

problem, as did Howland and Dana (1913). The latter method is made possible by the limited range of sizes available to the human body.

The author sought an empirical formula of the second kind among the family of equations, $Y = \dfrac{aX + b}{X + c}$, where a, b, and c are constants.

This type of function was chosen mainly because it permits simple calculations. It was tested with various integral values of a, b, and c. The final and most useful result was:

$$SA \ (m.^2) = \frac{4W + 7}{W + 90} \text{ where W is weight (kg.).}$$

In statistical terms this is not a best-fitting formula, but it is accurate enough over the range of weights between 1·5 kg. and 100 kg., and it has the advantage of easy calculation. Its accuracy has been calculated and compared to that of the most accurate previously proposed formulae, on the basis of the surface area measurements used by Boyd (1935) for formula evaluation. The results appear in the Table. The Figure shows the curve traced by this formula and its relation to the data compiled by Boyd (1935).

It will be noted that only formula 5 is significantly more accurate than the presently proposed method, and that this difference is slight despite the incorporation of height in the Boyd formula. The present formula seems quite adequate for use in determining the basal metabolic rate, being at least as accurate as the widely used Du Bois formula.

The calculation of $SA = \dfrac{4W + 7}{W + 90}$ can be simplified further by the following instructions:

(1) Weight in the denominator may be rounded off to the nearest kg.

(2) Weight in the numerator may be rounded off to the nearest quarter kg.

(3) No purpose is ever served by calculating surface area more precisely than to 0·01 m.^{2} Two significant figures are ample for prescribing drugs and fluids.

TABLE

Deviation of Estimate from Measured Surface Area of 220 Subjects for Various Formulae*

Author	Formula for Surface Area†	Weight					
		1·5 to 3 kg.		Over 3 kg.		1·5 to 100 kg.	
		No. of subjects	RMSE‡	No. of subjects	RMSE‡	No. of subjects	RMSE‡
Meeh-Boyd	$SA = 10\cdot53\ W^{2/3}$	23	11·7	197	7·9§	220	8·4
Boyd	$SA = 4\cdot688\ W^{0.8168-0.0154\ \log W}$	23	9·8	197	7·1§	220	7·4
Du Bois	$SA = 71\cdot84\ W^{(kg.)\ 0.425}\ H^{0.725}$	23	9·4	197	8·3	220	8·5
Du Bois-Boyd ..	$SA = 3\cdot93\ W^{0.425}\ H^{0.725}$	23	8·7	197	7·6	220	7·8
Boyd	$SA = 3\cdot207\ W^{0.7285-0.0188\ \log W}\ H^{0.3}$	23	9·8	197	6·3§	220	6·7
Present author ..	$SA\ (in\ m.^2) = 4\ \dfrac{W\ (kg.)\ +\ 7}{W\ (kg.)\ +\ 90}$	23	11·8	197	7·4	220	8·0

* Calculated from Tables 18 and 19 in Boyd (1935) except as indicated. ‡ Root mean square percentage error.
† Surface area given in cm.², weight in g., and height in cm., except as indicated. § Quoted from Table 19 in Boyd (1935).
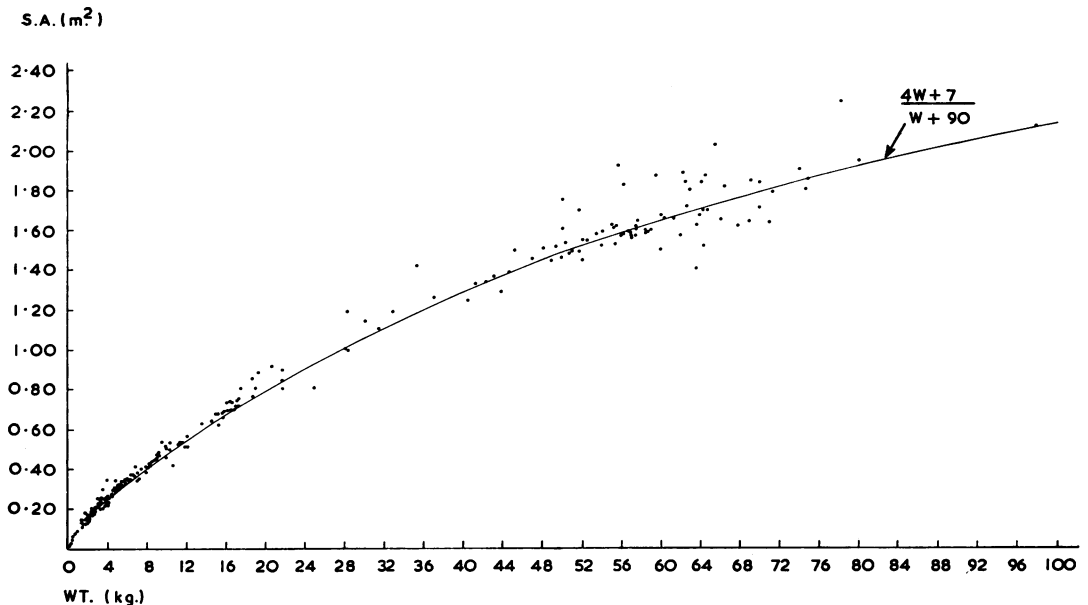

FIG. 1.—*Relation between weight and surface area, data from observations of Boyd (1935), and graph as calculated from the proposed formula.*

If one wishes only the proportion of adult surface area possessed by a child of given weight, the formula $\dfrac{SA\ of\ child}{SA\ of\ adult} = \dfrac{2\ W\ +\ 3}{W\ +\ 72}$ will be equally accurate.

It is hoped that these formulae will facilitate surface area calculations at the bedside.

Summary

A simple formula has been presented for calculating surface area from weight, $SA = \dfrac{4\ W\ +\ 7.}{W\ +\ 90}$ It applies to the weight range between 1·5 and 100 kg. with no less accuracy than the Du Bois formula, and it is recommended for use not only in prescription of drugs and fluids but also for calculation of the basal metabolic rate and other physiological indices.

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